ON CLINTON CONGLOMERATES AND WAVE MARKS IN OHIO AND KENTUCKY[1].

WITH A RÉSUMÉ OF OUR KNOWLEDGE OF SIMILAR OCCURRENCES IN OTHER SILURIAN STRATA OF THESE STATES, AND THEIR EVIDENCE UPON PROBABLE LAND CONDITIONS.

CONTENTS.

[1] Continued from Vol. III., No. 1, p 50.

PEBBLES AND WAVE MARKS IN THE ONEIDA, MEDINA, AND CLINTON GROUPS.

The Medina of Ohio and Kentucky furnishes so few facts of interest in this connection, and in places so difficult to distinguish from the Clinton, that it will not be considered separately but will be discussed under the above heading.

Observations of the Kentucky Survey.—No *Oneida* is exposed in Ohio. In Kentucky a conglomerate two inches thick, with the characters ascribed to the Oneida conglomerate of New York, is found in Boyle county.

Medina.—The rock supposed by Kentucky geologists to belong to the Medina is exposed in Lincoln county. Here it reaches a maximum thickness of 35 feet. In the western part of the county it is thinner. The whole series has the appearance of having been deposited largely or entirely by currents, and sometimes, probably, in the face of waves, as at several points one or two layers have a wave-like structure. In Garrard county the Medina has a maximum thickness of 35 feet, decreasing towards Madison county, northeastward. In Clark county the total thickness of the Medina is probably 20 feet, including nine feet of sandstones and shales at the bottom, and 11 feet of limestones and shales at the top. Eastward, in Montgomery county, these shales increase in thickness. Only 10 feet are accredited to the Medina in Bath, while 20 feet are given for Fleming county, and the same thickness, 20 feet, also for Mason county.

The Medina in Marion county measures only 14 feet. In Washington county it seems to occur with a thickness of 30 feet in one case, but another section gives 14 feet. In Nelson it varies from three to 20 feet. In Oldham county it varies from 10 to 30 feet.

Taking into consideration only the area between Marion and Bath counties, the Medina seems to thicken towards the southeast. Between Washington and Oldham counties its thickness is very variable, and in Fleming and Mason counties the thickness is apparently greater than in Bath on the south, and certainly surpasses that of known exposures in Ohio. Wave

marks are mentioned only from the most southern county—Lincoln. This fact should be considered in connection with the occurrence of the Oneida conglomerate in Boyle county, another very southern county.

Clinton. a, Crab Orchard Shales.—These shales reach a maximum thickness of 40 feet in Lincoln county. Intercalated among them are a few hard, smooth plates of thin limestone. These plates, and sometimes the shales, have a curved structure, and at times some of the laminæ overlap the thinned-out edges of the others. In Garrard county they vary from 16 to 25 feet. In Clark county these shales are only seven feet thick. They occur in Montgomery county, but their thickness is not mentioned. The shales appear in Bath county, but form there the lower part of the recognized Clinton Group, and will not be discussed in this connection. In Marion county the thickness is 20 feet. In Nelson county has diminished to two or three feet.

The presence of the Crab Orchard shales as a representative of the Clinton is of interest chiefly in showing the general thickening of such detrital deposits southward.

b, Clinton, Proper.—Above the Crab Orchard shales, in Montgomery county, there are rough-bedded heavy limestones. The massive layers overlying the shale are somewhat heavier, and in one or two places one of them shows a wave-like structure with large ridges. Rarely there is a layer of even-bedded stone. The same wave-marked layer occurs in Bath county, three feet above the shales, and 18 feet above the base of the Clinton. It is from 10 to 14 inches in thickness, marked with ridges from four to six inches in height and about 26 inches from crest to crest. The ridges are not a regular curve, but are somewhat sharpened at the top. This wave-marked layer occurs with the same persistence and at the same horizon in Fleming and Lewis counties. It is probably the layer discovered by Locke in the Clinton near West Union, Ohio, to which reference will be made later.

The oölitic iron ore is quite characteristic of the Clinton along the eastern side of the Cincinnati anticlinal axis, and its

Kentucky extension. In the report on Garrard county the statement is made that some "shot" iron ore comes from some place in the Crab Orchard shales, but it was not found. Red hematite iron ore, the oölitic variety, is mentioned from northeastern Clark and Montgomery counties. The oölitic iron ore is well characterized in Bath county and is definitely located there about four feet above the wave-marked layer and about 23 feet above the base of the Clinton. It varies in thickness from a few inches on the Montgomery line to nearly three feet on the eastern side of the county. In Fleming county it is sometimes absent, and sometimes appears at its proper horizon, but very much diminished in thickness. It is seen also in Lewis county, and is well shown at various localities in Ohio, where it also occurs only along the eastern side of the anticlinal axis. Its occurrence usually a short distance above the wave-marked layer may be of some significance. The fact that the wave-marked layers and the oölitic ore in both Ohio and Kentucky are confined to the eastern side of the axis is certainly very suggestive as to the conditions under which the Clinton was deposited there.

Chert is found in the Clinton in Henry county, the horizon not stated. In Nelson it occurs towards the top of the Clinton. In Marion county it is common. Its best development however seems to be in the northeastern counties, in Bath, Fleming, and Mason, where it occurs in the heavy limestones toward the base of the Clinton. This same horizon it occupies in Ohio. In Bath county, the general thickening of these heavy beds eastward is noted.

For the sake of com pleteness, two peculiar occurrences should be noted, which deserve fuller study in the field. Near Fredericktown, on the western side of Washington county, several inches of conglomerate occupy a position just underneath the heavy limestones of the section, presumed to be the Niagara. This would place it at the top of the Clinton. The conglomerate was composed of fragments of iron ore, probably the remains of the Clinton iron ore beds, cemented in a sandy shale. This conglomerate probably once extended over the entire country. In

Garrard county, above the Crab Orchard shales, occur one or two layers of limestone, which contain small rounded grains of clear quartz. Both of these occurrences are in southern counties, and they are probably good indications of strong wave action, with shallow waters, at the close of the Clinton age in this direction.

Observations of Dr. John Locke.—The locality in the Clinton investigated is along Lick Run, three to four miles northeast of West Union. This is 12 miles a little east of south of Elkhorn creek, and 50 miles east of south from the Todd's Fork locality. Waved layers were found. These are mentioned on page 244 and on plate 6 of the first report of the Geological Survey of Ohio, 1838. According to the section two waved layers, 20 inches apart, were found. It seems difficult however to believe the occurrence of the flinty layer at the top of the Clinton. The region near West Union would probably offer information pertinent to the present subject.

OBSERVATIONS BY THE WRITER IN OHIO.

Todd's Fork.—About two and a half miles north of Wilmington, the pike to Xenia crosses Todd's Fork. In the immediate neighborhood, along the stream, are numerous exposures of the Dayton limestone and of the top of the Clinton. Their junction can be best studied by following the stream eastward a short distance. Towards the top of the Clinton is found the peculiar brown purple rock also seen at Wm. Alexander's near Sharpsville. It contains in places the peculiar branching masses of fragmental material resembling the so-called fucoidal markings, also seen at Alexander's. In other courses of this purple rock, just beneath the Dayton limestone, was found a new brachiopod, a Craniella. The ferruginous red rock, so abundantly exposed a mile down the stream, was not seen here. Under the purplish layers the rock is brownish in color and contains numerous fossils. Going down the stream from the Xenia pike bridge, exposures of the Clinton are abundant. Wave marks were not seen at all. At several points cross-bedding is very marked, especially opposite a house belonging to Isaac Cline, of Wilming-

ton, but now inhabited by E. D. Miars. Nearly opposite, but a little down stream, a few stray pebbles were found in the Clinton. In order to satisfy myself that I was dealing with genuine pebbles and not with concretions, accidental layers of peculiar character, or rolled stromatoporoids, it was necessary to break open most of these. But on the south side of the stream occur two pebbles whose character would be acknowledged by any geologist, the larger one being 7½ inches long, 5¾ inches broad, and 1½ inches thick. Since the chief value of these pebbles lies in the fact that they are *in situ*, they were indicated by a mark pointing towards them, and it is hoped the pebbles will not be removed by visiting geologists. Pebbles were very scarce in the Clinton, only about six pebbles were found whose character was unequivocal. They were evidently derived from the Clinton layers immediately beneath. Following the stream southwards, nothing of special interest occurs until we reach the well-known Todd's Fork section, described in an earlier paper. It is on the north side of the stream, about three hundred feet east of the bridge, by which the Quaker Centre pike crosses the fork. Here the ferruginous, red-brown, oölitic, fossiliferous Clinton is well developed at the top of the section, these characters disappearing on going downward in the section, so that six feet below the top the rock is pinkish in color and has but few fossils. The Clinton section is here 18 feet. The lower two-thirds is light pink in color, and contains few recognizable fossils, although on closer examination the rock is seen to be a mass of crinoidal fragments, consisting especially of pieces of the narrow stem of some crinoid. Associated with the ferruginous layer is some of the purple tinted rock already mentioned. In it was found a thin pebble, consisting of the iron-stained limestone found immediately below. All of the pebbles found in the Clinton of Todd's Fork resemble the Clinton rock lithologically. In the pinkish rock, forming the lower two-thirds of the Clinton, evidences of stratification are in places rather common; at a few places a sort of cross-bedding was noticed. This can be seen at the Todd's Fork section just mentioned, and also up stream a short distance

east from Miar's house. Under the Clinton, at the section, the Medina is found, five feet thick, containing annelid teeth towards the top. Beneath this are said to be about eight feet of blue clay, some of which can be seen on the north side of the creek, after following the stream westward for some distance.

The small number of the pebbles found should be especially noted.

Farmer's Station.—On the Baltimore & Ohio Railroad, fourteen miles a little east of south of the Todd's Fork locality. Going south from the station on the Lynchburg pike a little over a quarter of a mile, then diagonally eastward by a road coming in from the left, crossing a bridge across a small stream, the house of Anderson D. Johnson, formerly the home of George Grubb, is reached. It is about half a mile from the station. Directly west of the house, in the bed of the stream just mentioned, the base of the Clinton is found exposed (locality 1). Large fragments collected upon the banks show this rock to vary, some courses being blue and compact, weathering drab, others being naturally more whitish, and fairly fossiliferous. The fossils were: Proetus determinatus, head, distinct; Illænus ambiguus, pygidium; Lichas breviceps, glabella; Phacops trisulcatus, heads and pygidia, rather common; Dalmanites Werthneri, a good head; Leptæna rhomboidalis, middle size; Strophomena (Strophonella) patenta; Orthis elegantula, var. parva; Ptilodictya lanceolata, var. Americana; Phænopora simplex, nov. spec. the form with simple fronds, slightly curved, otherwise having all the appearance of a single branch of *Phænopora multifida.*

Some slabs show round blotches, one-half inch to one inch in diameter, now brownish clayey masses; these may once have been limestone pebbles which decayed more rapidly than the cementing limestone. There was no *good* evidence of the former existence of pebbles in these rocks. The presence of cherty slabs showed how far north this element of the more southern exposures of the basal Clinton extends. Sometimes fossils occur both above and below in immediate contact with the chert,

sometimes preserving their original calcareous shell. Farther north, on the east side of the creek, a hole dug in the side of the hill (locality 2) showed a more massive and more ferruginous rock, many crinoid beads, belonging to the Middle and Upper Clinton. No good section is exposed.

Sharpsville.—Seventeen and a half miles slightly east of south of Wilmington, and about three miles a little north of east of Lynchburg; in the northwest corner of Highland county. The section starts at the east and west road, about two-thirds of a mile north of Sharpsville, near the house of Wm. Alexander. Nearly opposite the house, on the south side of the road, is a quarry opened up into the Dayton limestone (locality 3). The base of the Dayton limestone here contains Favosites favosus, both the large and small varieties according to Rominger, a branching compound coral, crinoid stems, and a few other fossils, more or less frequently. Immediately under the Dayton limestone is found the deep red ferruginous Clinton. This is best exposed in the little streamlet southeast of the quarry. Eastward along this stream (locality 4) the top of the ferruginous Clinton presents a lithological characteristic difficult to describe, except that it is a sort of consolidated marl of peculiar color. This marl surface contains a number of fossils characteristic of the so-called Beavertown marl, overlying the Clinton south of Dayton and also south of the Soldiers' Home. These are Raphistoma affine, Cyclora alta, Loxonema subulatum? one of the small Tellinomyas, Orthis biforata, Orthis elegantula, Orthoceras inceptum, and Calymene vogdesi. Of these fossils the Raphistoma and Orthoceras were also found in the ferruginous Clinton at Todd's Fork. The present locality is the most southeastern exposure, containing the Beavertown marl fauna, so far known. This ferruginous rock is about two feet thick, and is underlaid by a pinkish rock containing many crinoid stems, Platyceras (Platystoma) niagarense, the small Soldiers' Home form, and Orthis elegantula, corals, and Rhinopora verrucosa. This pinkish Clinton is well shown in the field east of the house of Daniel Sharp, along the more southern parts of the streamlet above

mentioned. Above the pinkish Clinton, the ferruginous Clinton at times shows dark red sandy phases in which Rhynchonella acinus var. convexa is often a common fossil, even the calcareous shell being at times preserved. This phase may be seen over the pinkish Clinton, southeast of Sharp's house, between the house and the stream. Farther southward is the fairly extensive quarry of Daniel Sharp, where the Dayton limestone is well shown (locality 5). Passing the quarry and descending the stream, the fence separating the land of Daniel Sharp from that of A. K. Johnson is reached (locality 6). The fence rested upon a whitish limestone block containing limestone pebbles, of a character lithologically similar to the rock belonging to the Lower Clinton of this section. From this point on, for a considerable distance down the stream (to locality 7, which is a heap of boulder fragments), boulders of Clinton rock containing pebbles are of more or less frequent occurrence. Since they are not found in the *in situ* exposures of the Lower Clinton seen along Turtle creek, which will be described later, it is evident that the boulders belong to the Middle Clinton. At the fence above mentioned, the cement of the pebble-bearing rock contained Illænus ambiguus, Meristella umbonata and Orthis biforata, var. daytonensis. Farther down, the cement contained abundant and characteristic Clinton fossils. The pebbles were often of fair enough size, at times five or six inches in diameter. The pebbles resemble lithologically the more sandy Clinton beds just beneath. Continuing southward, the stream enters Turtle creek. Following its course downward or westward, a continuous line of exposures is found along the northern bank opposite the cluster of houses called Sharpsville. The total exposure includes a section of 13 feet. Beginning nearer the eastern end of the exposures (locality 8) and going downwards, we have at the highest point 16 inches of a sandy stratified limestone; then 12 inches of solid white limestone with fossils; 13 inches of sandy stratified limestone; six inches of whitish solid fossiliferous limestone; 30 inches of sandy, well stratified limestone; one inch of chert; two inches of sandy limestone; two to three inches of white chert; 24

inches of unevenly-bedded rock with fossils; one inch thickness of a thin, sandy layer, very undulated, like ripple marks where waves have crossed from various directions. Their importance was not appreciated, when observed, and their direction was not carefully observed. Judging from the memory alone the larger ripples had a general northeast course and indicated currents transverse to this direction. Below this layer were found 10 inches of a whitish rock, lithologically like the Dayton limestone, and like it, with a very uneven surface to the upper side of the layer. Tracing this layer westward to the more western part of this line of outcrops as far as a place known as John Arment's quarry (locality 9 in the bed of the creek), the cherty layers beneath the same are well exposed. First there is a layer of white chert four inches thick, then four inches of a brownish rock, then four inches of chert again, and finally 24 inches of limestone, whitish above becoming bluish below, and quite fossiliferous, though hardly more so than some layers farther up in the series. In this basal layer of the Clinton the following fossils were found: Illænus ambiguus, Orthis biforata, Ptilodictya lanceolata, var. americana, Clathropora frondosa, Phænopora magna, Rhinopora verrucosa, and Phylloporina angulata.

Underneath the Clinton lie four feet of a bluish rock, the so-called Medina, which is here quarried. It contains, in addition to the so-called branching fucoidal impressions, a species of Orthis, on the type of Orthis calligramma, but with about 44 radiating plications, and annelid teeth. The Orthis does not closely resemble the more nearly related Clinton species. It will be remembered that annelid teeth also occurred in the so-called Medina at the Todd's Fork locality.

Under the Medina is a bed of blue clay, but its thickness has not yet been determined. The Cincinnati rock can not be far beneath.

Unfortunately it was impossible to determine, with the means at hand, the thickness of this section. It is hoped some one may undertake this. But it was difficult for the writer to believe that the thickness of the entire Clinton even approached 50 feet,

the thickness usually assigned to the Clinton in its southeastern exposures.

Rocky Fork.—On the pike leading to Belfast, one and a-half miles from Hillsborough. At the bridge, on the south side of the stream, the top of the Clinton is shown, underlying the Dayton limestone. East of the bridge, the east bank of the stream gives good exposures. Only a hasty observation was made. The fossils found, such as Orthis elegantula, were not conclusive. The strongly ferruginous character of the rock, especially an oölitic iron layer thinly interstratified at one place, in connection with its position beneath the Dayton limestone, sufficiently identified it. The writer failed to trace the Clinton eastward along Rocky Fork, but on the contrary found evidence of chert beds belonging to horizons quite a distance above Dayton limestone, at the lowest exposures next seen on going up stream. In this chert Encrinurus ornatus, Hall, was well shown in one case. An associated rock contained abundant Meristellas, much shorter than Meristella cylindrica, as seen in full-sized cabinet specimens from Hillsborough. Bisher's dam is only a short distance down stream from the bridge, and no very good reason can be seen there why the Clinton should not continue to be exposed for some distance down the stream. Unfortunately the writer had not the time to search in this direction.

Belfast.—Thirty-four miles southeast of the Todd's Fork locality, and 17 miles southeast of Sharpsville.

I. *The William Haigh Farm section.*—Going north along the road through Belfast, about half a mile from the center of the village, and then taking the first road going westward, a little stream, crossing the road, is soon reached. Following this stream southward, the Dayton limestone is found exposed in the creek bed, within a short distance of the road (locality 10). Continuing down stream the following very characteristic section is exposed. Beneath the Dayton limestone is the ferruginous crinoidal Clinton, containing Leptæna rhomboidalis, Phænopora multifida, and Rhinopora verrucosa. Within 200 feet of the road the ferruginous layer is conglomeritic, the pebbles being

of variable diameters, up to three inches. The pebbles now have the appearance of consolidated brownish clayey material; one of the pebbles contained oölitic grains similar to those of the general ferruginous rock in which these pebbles were imbedded. Three hundred feet from the road are bluish, sandy, stratified, non-fossiliferous layers similar to those near the top of the Turtle Creek section near Arment's quarry. A little further down stream the crinoidal rock contained pebbles, and one of these was made up of the same purplish ferruginous marl which constitutes part of the uppermost ferruginous layer of the Clinton in the present section. These pebbles were probably obtained from the Upper Clinton, not far distant. Farther down stream the rock contained Platyceras (Platystoma) niagarense, the little Soldiers' Home form, and Orthis elegantula. Six hundred feet from the road Illænus daytonensis, Orthis biforata, and Orthis elegantula were found in a whitish limestone; a single blue limestone pebble was seen. About 650 feet from the road good cross-bedding was noticed in the sandy stratified Clinton on the east side of the creek. In one layer the stratification lines dip 25 degrees southward; immediately overlying this layer is one with perfectly horizontal stratification. Farther down stream the rock becomes more massive, with few fossils, but opposite the barn it contains Clathropora frondosa, and a few stray bluish pebbles, two to four inches in diameter, lithologically similar to the Clinton rock immediately above and below. In a layer full of crinoid beads, together with Orthis calligramma, var. eu-orthis, Strophomena patenta, and Phænopora expansa, was found a stray small blue pebble one inch in diameter. Just below, opposite Wm. Haigh's house (locality 11), were found Illaenus ambiguus, Leptæna rhomboidalis, Strophomena tenuis, Orthis biforata, var. daytonensis, the larger form of those with three plications on the median fold. Below the house in the creek bed were slabs containing very small pebbles, up to one inch in diameter; Cyclonema bilix was seen here. Below this rock comes the very siliceous but not cherty rock which here constitutes the base of the Clinton. On the opposite side of the

creek a somewhat higher exposure shows four inches of chert overlying 24 inches of the sandy stratified Clinton. The structure of these elements of the basal Clinton can be better understood by a reference to the Smart section, next given. Underneath the Clinton on the west side of the creek are four feet of a massive greenish rock, constituting the so-called Medina of northern sections, and also containing the same annelid teeth, although in order to find these readily it is necessary to go southeastward to the southwestern angle of the hill caused by the cutting action of this small stream and the fork of Brush creek, a short distance to the southward, into which the stream flows (locality 12). Beneath the Medina are 22 inches of a bluish clayey material, which, however, has become somewhat indurated, and presents a shaly structure instead of the usual homogeneous clayey consistency. Quite a number of springs make their appearance between the Medina and this blue clay layer. Underneath is the horizon of the Cincinnati group.

II. *The J. V. D. Smart sections*, including part of the former Charles Dalyrymple farm. Going from the center of Belfast south to the bridge, westward to the exposure of the basal Clinton, bending towards the southwest about a quarter of a mile, and then taking a road at a right angle to the latter, that is going northwestward, two sets of exposures are found before the abrupt turn of the road to the westward is reached, one of these, about half way along the northwest stretch of road, the other near its northern end. The first of these exposures (locality 13) is along a small streamlet, running only in wet weather; it is only a short distance east of the road. The uppermost layers are cross-bedded, and overlie a conglomeritic layer 12 inches thick, with many flat pebbles, some of which were four to six inches in diameter, and did not show signs of fossils. Farther northward at the second locality (locality 14) the conglomerate is exposed in the road bed. Here one of the pebbles, of whitish sandy limestone, stained brownish by iron compounds where weathered, contained a young Rhynchonella, which is probably Rh. scobina, and about half a dozen valves of Rhynchonella

acinus var. convexa, the large Clinton form found also in the upper or ferruginous Clinton in the Sharpsville section. This showed that the pebbles were of Clinton and not of Cincinnati age, as hitherto stated. The lithological character of the various pebbles was similar to the various Clinton layers known in this vicinity, but not to any known Cincinnati rock. Eastward from this road bed exposure the conglomerate is well exposed along a more northerly situated streamlet, running, as did the last, only in wet weather (locality 15). There is evidently an upper horizon of the Clinton, scarcely more than 15 inches thick, which is full of pebbles. Many of these are eight to ten inches in diameter. The pebbles are always very flat, and rarely contain fossils. They evidently are chiefly derived from the stratified, more sandy looking Clinton layers, which characterize the lower half of the Clinton, but which are also found very far up in the series. At the present locality, this sandy stratified rock forms a layer immediately above the conglomerate layer, and is abundantly shown in the remainder of the section on following the stream eastward. Both of the streams mentioned flow eastward, and join before emptying into the main fork of Brush creek. The base of the Clinton, with its underlying Medina, is well shown a little east of this junction, on the north side of the stream (locality 16). The top layer showed one of the annelid teeth characteristic of this horizon. Following the hill-side along the western side of the open valley, the fine road-side exposure of the base of the Clinton, to which reference has already been made, is seen (locality 17). It is on the land of J. V. D. Smart, on the north side of the road leading from Belfast to Fairfax, and not far west of the bridge over the fork of Brush creek southwest of Belfast. At the top, 12 inches of the sandy looking limestone were shown. Underneath were four inches of chert; this was the chert layer seen on the eastern side of the creek in the Wm. Haigh section. Below were 26 inches of massive limestone with cherty nodules and also with cherty bands along the vertical crevices of the rock, showing the secondary nature of this chert. Then, 20 inches of shelly limestone, meaning by this

a limestone that weathers into fragments one inch or slightly more in thickness, and four to six inches in length, tapering out more or less towards the edges, so as to totally destroy its value as a building stone. This limestone also contained siliceous and cherty nodules, and was in itself quite siliceous. Below this were 24 inches of poor shaly limestone, under which the so-called Medina made its appearance. Following the steep hill-sides along the southern side of this fork of Brush creek, eastward from this exposure, the basal portions of the Clinton and the underlying Medina are well shown as far east as the next bridge, where the pike from Belfast to Loudon and Locust Grove crosses the fork.

III. *Bridge exposure.*—Along the pike leading from Belfast to Locust Grove, the locality mentioned just above (locality 18). Here the so-called Medina is well exposed; it is quarried, and is considered an excellent building stone. It will be remembered that it was quarried also at Arment's quarry in the bed of Turtle creek, in the Sharpsville section. The top layers of the Medina here contained a considerable number of annelid teeth, and also a single but good specimen of Halysites catenulatus.

Returning to Belfast from this bridge, the Clinton limestone is exposed on the side of the road, on the north side of the main valley formed by the fork (locality 19). The section on the Smart farm could be readily measured with proper instruments. The conglomerate layer is evidently nearly at the summit of the Clinton. Estimates made by eye alone would hardly give the Clinton here a greater thickness than 35 feet.

Elk Run.—Going north from Belfast, take the first road going east; two miles from Belfast the road crosses Elk Run, across an iron bridge. In the bed of the creek the top of the Clinton is shown (locality 20). At the top are 20 inches of ferruginous Clinton, showing cross-bedding, and a few pebbles. Near the middle they contain also a thin layer of blue clay. If the memory is not at fault similar thin blue-clay layers are seen near the top of the Clinton in the Wm. Haigh section. The fact was not recorded at the time of observation. The fossils

found in this ferruginous rock (which included both sandy and oölitic layers) were Platyceras (Platystoma) Niagarense, the small Soldiers' Home form, Leptæna rhomboidalis, Orthis elegantula, and good specimens of Aspidopora parmula. By far the most interesting feature of the locality however was the presence of great wave marks, wonderfully distinct and well exposed for a distance of a hundred feet down the creek. The line of strike of these wave marks was magnetically about north 65° east. The crests of the wave marks were about two inches above their greatest depressions, and the distance from one crest to the next was on the average about 28 inches. They sloped northwards a little more steeply than southwards. This wave-marked layer is only from one to two inches in thickness, and immediately overlies a great mass of pebbles, imbedded in the Clinton just beneath. These pebbles sometimes project strongly into the sandy layer above, which shows the wave marks. The pebbles are on the average larger than at any place where pebbles have so far been seen in the Clinton. Plenty of them are 12 inches in diameter, and many of them range between four and eight inches. As usual, the pebbles are only an inch to an inch and a half in thickness. Lithologically they are similar to the sandy stratified layers of the Clinton limestone, found characteristically in the lower half of the Clinton in this part of the state, and occurring also at higher levels. If there had been any doubt hitherto about the Clinton age of these pebbles, it was dispelled by the fossils found in some of the pebbles at this locality. The pebbles here were again almost invariably unfossiliferous, but there were so many pebbles in the rock, and the conglomerate layer was so well exposed, that it was possible to break out enough pebbles in a short time to make a satisfactory examination. Three of the pebbles contained fossils. The forms found were Illænus daytonensis, fragment of a glabella, a rostrum probably belonging here, and a very good pygidium; Cyphaspis clintonensis, the middle parts of two heads in a very good condition; half a dozen specimens of a small form of Orthis elegantula, and a young Rhynchonella, probably Rh. scobina.

The first two species named clearly identify the rock from which these pebbles were derived as Clinton, a fact already manifest from a consideration of the lithological features of the pebbles, to those thoroughly acquainted with the Clinton.

Ellenville section.—Ellenville lies about four and a half miles east of Belfast, farther on along the same road which leads to the Elk Run section. In loose boulders of the Clinton good specimens of Strophomena patenta, Aspidopora parmula and other characteristic Clinton fossils were seen. The section here described begins about half a mile south of Ellenville, along the east side of the pike, where the Dayton limestone of excellent quality with courses 12 inches and more in thickness is exposed at several localities, usually east of the culverts where streamlets cross the pike (localities 21 and 22). Underneath the Dayton limestone is found the deep red sandy Clinton, and below this the ferruginous and at times oölitic Clinton, but no pebbles were seen. About a mile south of Ellenville after crossing a somewhat larger culvert, and where the pike ascends a somewhat steep hill, the Dayton limestone is exposed in the woods (locality 23) at some distance east of the pike and at a fair elevation. Tracing it eastward, it seems to rise in altitude. Along the pike (locality 24) the Clinton is well exposed. It is often well cross-bedded and in different directions. Ascending the hill, quite a thickness is well shown. Reaching the top of the hill, a little streamlet, descending rapidly to the middle fork of Brush creek, again well displays the Middle and Upper Clinton (locality 25). It is deeply red in color, of a sandy type, and frequently cross-bedded, but does not show, where examined, any pebbles. At the creek, a short distance below the point of entrance of the little streamlet just mentioned, the base of the Clinton is well exposed (locality 26). About eight feet of the Clinton are seen, containing cherty concretions in nodules and along vertical cracks, and showing the so-called shelly layers mentioned in connection with the Smart section near Belfast, and also some very siliceous but not exactly cherty layers. Meristella umbonata was found here.

Peebles Station.—About 10 miles southeast of Belfast, and 44 miles southeast of the Todd's Fork locality.

Following the Cincinnati, Portsmouth & Virginia railroad westward from Peebles, a high trestle is crossed, west of which the Niagara shales are well exposed. Still farther westward, about two miles from Peebles station, there is a small house on the south side of the railroad (locality 30). It is on the land of Tom Gardner. The farm line runs a short distance east of the house, and east of the line is the farm of James Philips. Along the railroad, 300 feet west of the house, the Dayton limestone is well exposed (locality 31). In the middle courses of this Pentamerus oblongus is found. In the report of the Ohio Geological Survey for 1870, page 280, the following statement is found: "Col. James Greer, of Dayton, has in his cabinet a specimen obtained from the Dayton stone, the lowest member of the Niagara series, which is probably Pentamerus oblongus, in somewhat abnormal form." The present is as far as known the first instance in which the occurrence of the Pentamerus in the Dayton limestone is authenticated by its reference to a locality where the rock is evidently *in situ*. So far no lower horizon for this fossil in Ohio is known. It is additionally interesting for presenting the original shell, although the shell usually splits away and leaves the cast, when an attempt is made to work it out. The Dayton limestone is also exposed some distance east of here, on the Philips farm (locality 28), in the bed of the creek which follows the railroad on its southern side. Here slabs sometimes contain Pentamerus in abundance. The Clinton is well exposed beneath. The upper portions are ferruginous, either sandy and stratified, or at times oölitic. At one point it seemed possible to trace a sort of wave-marking running north 40° west. In the light of later discoveries in the Cincinnati, these traces may have some value, though in themselves unsatisfactory. In the sandy layers the stratification is sometimes well marked. The Clinton is made up of very different courses, some of them sandy and red, others oölitic, crinoidal and deep red, and still others of very pure limestone and white. A course

of the last kind is seen a short distance east of the farm line mentioned (locality 29), and is very rich in fossils. Down the stream, across the line, behind the house (locality 30), the Clinton bowlders show the nearest approach to pebbles seen in this section. Strongly rounded specimens of Favosites, Heliolites, and Cyathophyllum are quite common here and are also found farther up stream. Behind the house some specimens do not show structure but may possibly have been strongly rounded stromatoporoid sponges. It would require microscopic sections to determine the matter. Farther down stream the reddish color disappears, and where the creek passes under a bridge to the north side of the railroad the west embankment of the bridge (locality 32) exposes 8 feet of the basal part of the Clinton. It has a very irregular structure, similar to that called shelly above, is very siliceous, and contains nodules of chert. The piers of the bridge on this side were constructed by going down into the bottom of the creek bed, and there Cincinnati rock was struck, showing well-known Cincinnati fossils in abundance. At the top, the thin Cincinnati limestone fragments show a thin coating of a shaly material, in which annelid teeth are found. The total section of the Clinton is therefore shown along this stream. It hardly exceeds 30 feet, as determined by estimates made without the assistance of instruments. The top layer of the Cincinnati group shows abundant encrinital remains, and numerous specimens of a small Tentaculites. Leptæna sericea is common. The following species were observed in the Clinton, chiefly in its upper courses, though the middle courses are in places rich in fossils; but the latter were not examined: Illænus ambiguus, pygidium in the Lower Clinton; Calymene vogdesi, both of large and medium size; Cyclonema bilix, Leptæna rhomboidalis, Strophomena patenta, Orthis calligramma var. eu-orthis, Orthis biforata var. reversata and var. daytonensis, the latter with only three plications on the median fold; Orthis elegantula, Rhynchonella scobina, Clathropora frondosa, Phænopora, a long simple frond 10 mm. broad at the top, species unknown, Aspidopora parmula, very common in the richly fossiliferous layer

east of the farm line, Heliolites sub-tubulatus, and Halysites catenulatus.

REMARKS ON SOME FORMATIONS ABOVE THE CLINTON.

Observations by the Kentucky Survey.—The *Niagara shale* seems to become thinner southward and westward in Kentucky, as far as can be determined from the statements that it is 100 feet thick in Lewis, Fleming, and Bath counties, 35 feet in Marion and Nelson, and 15 feet in Oldham, being sometimes entirely absent in the last county. It varies greatly in thickness. It is not mentioned from the most southern counties, but this may be partly owing to the difficulty in discriminating between the Niagara and the Crab Orchard shales in that region.

The *heavy beds of the Niagara* are seen in Pickaway county, Ohio, and extended thence as far as Highland county of that state. In Kentucky, judging from residuary fragments left on the bedded rocks, the eastern line of outcrop once extended from Bracken county to Nelson and part of Washington counties. Continuing in the same southwesterly direction it passed into western Tennessee. West of the line thus located, the heavy beds seem to have covered all the areas within the present regions of suitable outcrops in the states of Ohio, Indiana, Kentucky, and Tennessee. The beds therefore do not occur between Adams county, Ohio, and Washington county, Kentucky, the eastern and southern range of counties.

The *Oriskany*, on the contrary, occurs only in these counties, from which the heavy Niagara beds are absent, that is in the counties from Lincoln to Bath. It usually is a single layer 12 to 18 inches thick, but in Bath is three feet thick. It usually contains fish remains, which are often much rolled and rounded.

The *Corniferous* occurs west of a line which lies so much farther east than the line of outcrop described for the heavy beds of the Niagara, that it practically occurs at all suitable exposures in Ohio, Indiana, and Kentucky, and is absent only in the extreme east, in Adams and Lewis counties, the Ohio river counties of Ohio and Kentucky.

The *black slate* covered all regions of Kentucky where proper horizons are exposed at present.

Mention has already been made of the iron pebbles just beneath the heavy beds of the Niagara in western Washington county, and of the rounded grains of quartz above the Crab Orchard shale in Garrard county. In the geology of Lincoln county the statement is made that in nearly all the layers of the Upper Silurian and Devonian, and even in the base of the black slate, there are small transparent grains of quartz. These are nearly microscopic but they are well rounded. In the black slate they are mentioned from Nelson, Lincoln, Garrard and Clark counties. Wave marks occur in the black slate in Lincoln county and also in Clark county, near the base.

Unconformities.—In southern Clinton county and adjacent Tennessee the black slate rests directly upon the Hudson River rocks. In the northern parts of the county, and in Cumberland county, it rests upon the Cumberland sandstone. In Lincoln county both the Corniferous and the Oriskany appear below the black slate, but the Oriskany rests sometimes upon the Crab Orchard shale and sometimes on the Medina ; at one point a little Niagara limestone seems to come in above the Crab Orchard shale. In Marion county the Corniferous rests directly upon the Crab Orchard shales. In Garrard county the Corniferous frequently rests directly upon the Crab Orchard shale, but sometimes the limestone layer with rounded quartz grains, already mentioned, possibly Oriskany, intervenes. In Clark county the Oriskany is well recognized, and rests on the Niagara shale. All this is in keeping with the other facts already mentioned, in accordance with which the sandy, detrital elements increase in the Lower Silurian, in the Cumberland sandstone, in the Medina, the Crab Orchard shales, and various later rocks, on going southward.

As already stated, the heavy beds of the Niagara are absent in the southern and eastern counties of Kentucky. Going northeastward the Oriskany disappears near the middle of Bath, and the Corniferous in Fleming county. They do not appear again until Highland county, Ohio, is reached.

Observations made by the Ohio Survey and the writer. Springfield limestone.—Peebles station, about 10 miles southeast of Belfast, and 44 miles southeast of the Todd's Fork locality, on the Cincinnati, Portsmouth & Virginia railroad. Along the railroad about a quarter of a mile west of Peebles, where the railroad crosses a creek (locality 27), there are very good wave marks in the rock on the north side of the railroad, in a sort of quarry. The rock is of a bluish tint, and is some distance above the Niagara shales. It is presumably of the Springfield horizon. The crests of the waves run here north 3° east; they are about 3½ inches above the troughs of the waves, and are about 42 inches apart, showing therefore approximately the same characteristics as the waves of Clinton age in Elk Run. They descend more rapidly eastward than westward. The wave marks are seen at several levels through a thickness of 2½ feet of rock. Under the wave-marked courses is one marked by crossing ripples, on an equally large scale, such marks as can be seen on the seashore where the ripples from various directions cross each other and break up the regular wave markings. Just below, little pebbles, a quarter of an inch to one inch in diameter, occur at the base of the wave-marked beds. Their color now is gray, the surrounding material being blue. Otherwise they could hardly have been recognized. They are therefore not satisfactory pebbles. Where the railroad crosses the creek, 50 feet towards the southeast, the wave marks are shown over a larger area. The crests here run north 5° west.

Waterlime.—Ripple marks and suncracks are found in the Waterlime or Helderberg in Champaign county, and are used at Urbana for sidewalks. Suncracks occur in Fayette county near Washington, and also near the southeastern part of the county. At Rockville some of the courses are covered with suncracks and ripple marks. Indications of shallow waters occur also in Highland, Pike and Adams counties, according to Professor Orton (page 292, Report for 1870, Ohio).

Corniferous.—In Marion and Delaware counties, at the junction of the Waterlime and the Corniferous, the latter is largely

composed, locally, of rolled pebbles of the Waterlime. Many floated fragments of land plants, including branches of Lepidodendra, have been found in the Corniferous at Delaware and Sandusky, showing the proximity of land.

Hillsboro Sandstone of Highland county.—Professor Orton, in the 1870 report, page 283, wrote: "The only remaining division of this extensive series (Niagara) of rocks is the Hillsboro sandstone, the sixth member of the Niagara group in Highland county. . . . It is a unique and original contribution of Highland county to the general geological scale. Limestones and calcareous shales constitute the only kind of rocks that have been referred to this period hitherto, in the Mississippi Valley; *but at Hillsboro and on the eastern border of the county generally*, a siliceous sandstone of a good degree of purity is found terminating the series. . . . . The thickness of this sandstone at Lilley's Hill (at Hillsboro) is 30 feet, and no greater thickness is shown elsewhere. The sand that makes up the rock is fine-grained and but slightly cemented."

GENERAL CONCLUSIONS.

A brief résumé of the more important facts regarding the geographical distribution of wave marks and pebbles.—In the Trenton of Kentucky the wave marks and pebbles are mentioned only from the southeastern counties of the Blue Grass region, Garrard, Clark and Montgomery. The pebbles occur near the top.

In the Utica or "Lower Hudson," rounded limestone pebbles occur in the lowest bed in Washington county, and apparently also in Mercer, Boyle, Clark and Montgomery counties. These are again the southern counties, and lie in about the same set as those mentioned as containing pebbles in the Trenton. The occurrence of pebbles at West Covington, opposite Cincinnati, and the widespread distribution of wave marks wherever the upper strata of the Lower Hudson are exposed (the list of counties completely encircling the Blue Grass region of Kentucky) point to a more widespread exposure to wave action.

In the Middle Hudson wave marks are mentioned from near

the base in Washington county; also from Nelson county, both southwestern counties of the Blue Grass region. Their occurrence in Nelson county seems to be extremely doubtful. At the top of the Middle Hudson, and the base of the Upper Hudson, are arenaceous elements which increase in thickness and coarseness going southwards.

In the Upper Hudson wave marks appear in Oldham, Lincoln, Clark, Montgomery and Fleming counties of Kentucky and in Adams county in Ohio. Pebbles occur in Clark and Montgomery counties in Kentucky, and in Adams county in Ohio. With the exception of Oldham, these are the eastern counties in Kentucky and the southeastern ones of Ohio, in the Lower Silurian region.

At the top of the Lower Silurian comes in the Cumberland sandstone, which has its most marked development in the southern counties of Kentucky.

The Oneida conglomerate is barely represented in Boyle, one of the southern counties of Kentucky.

In the Medina, wave marks have been noticed only in one county, Lincoln, the most southern county of this region, and just southeast of Boyle. The Medina seems to increase in thickness southeastward in the eastern range of counties.

In the Clinton, wave marks occur in Montgomery, Bath, Fleming and Lewis counties, Kentucky, and in Adams and Highland counties in Ohio. These are the most eastern of the Clinton group counties. [It is approximately the same area over which, later, the Corniferous failed to extend. On approaching this area, the Oriskany of Kentucky thins out; it is a part of the eastern set of counties over which the massive limestones of the Niagara fail to appear.] The oölitic iron ore has a somewhat great extension, being apparently present in Garrard, and certainly in all the counties from Clark in Kentucky to Clinton county in Ohio. The Crab Orchard shales, which represent the Clinton in the southern counties, thicken going southward. Farther north they form only the lower part of the Clinton, and merge into the lower sandy limestone of this group. This

lower more sandy Clinton also thickens eastward. Pebbles were found in the Clinton only in Ohio, in Clinton and Highland counties, being more frequent in the latter.

Location of shallow waters as evidenced by pebbles and to a certain extent by wave marks.—In the late Trenton and early Utica or "Lower Hudson," shallow waters, as evidenced by pebbles and wave marks, occurred over the southern Blue Grass counties of Kentucky. In the late Utica, shallow water areas extended over the entire Blue Grass region of Kentucky as far as the Ohio side of this area near Cincinnati. In the early Middle Hudson shallow waters are again confined apparently to the southern counties, while towards the middle and close of the Upper Hudson, with the exception of Oldham county, the shallow water areas extended all along the eastern counties from the most southern one, Lincoln, as far as the most northern one, Adams, in Ohio. This location of shallow water areas in the eastern counties, instead of over the entire Blue Grass region during Upper Hudson times, will, if substantiated by future investigations, be very suggestive as to geographical changes during pre-Clinton times.

In the Oneida and Medina shallow waters again occurred in southern counties. But in the Clinton it is again the eastern counties, all the way from Clark in Kentucky to Adams in Ohio, which give the evidences of shallow waters.

In the rocks here discussed two kinds of materials occur—fossils or their comminuted remains, derived from the animal life of the Palæozoic seas of these regions, and detrital materials of a foreign nature, derived more or less directly from some land area. The detrital beds usually increase in thickness going southwards, and not infrequently also, though apparently to a less marked degree, on going eastward. The explanation for this may be that land lay in these two directions, but an equally suggestive way of stating what perhaps amounts to the same thing, is that these detrital remains may have been carried northward and westward by some ocean current which found its way northward along the eastern border of some Palæozoic continental area.

Conclusions to be drawn from wave marks and pebbles.—No one who is familiar with wave marks as made along long surf-beaten beaches of the ocean, can doubt for a moment the origin of the wave marks. Their unusual size will, however, attract attention even from one familiar with the work of the sea. Yet it must be remembered that we are familiar only with the wave marks left by the edge of the sea, where the force of the waters has been almost spent. It is readily conceivable that farther from the shore different results, at least as regards magnitude of wave marks, might be expected. It has always been a hope of the writer to, some time, be able to photograph the bottom of the sea after some great storm, along some exposed coast, with good sand bottom. This could readily be done by a camera properly constructed, using electric light as a means of illumination.

The magnitude of the wave marks here referred to would indicate free exposure to the sea, but would not determine much as to its depth. The writer does not know of large wave marks at great depths. On the contrary the largest he ever saw were at the mouth of Hampton river, in Massachusetts, considerably above low water mark. These fully equaled the wave marks of the Ohio rocks.

As regards the pebbles, all the evidence in the case of those found in the upper Utica, in the "Upper Hudson" and in the Clinton is to the effect that they were derived from practically the same beds as those in which they are now found imbedded. To be more precise, their lithological character and the contained fossils are always those of rocks belonging to the same bed in which they are now found or at best only a few feet farther down, but not sufficiently beneath to suggest their origin from a separate palæontological horizon, even on the basis of the most careful classification. Evidently the waters were shallow enough to permit erosion. This may have occurred without actual elevation of the rock above sea level, but it is more natural to suppose that such elevation above sea level did take place, that the land area was but slightly elevated and was soon again submerged, leaving the irregularly eroded surface a

play to the waves. If the association of wave marks with these pebble areas be remembered, it will be readily understood that the forces capable of leaving these marks could lift up the loosened slabs of Cincinnati group and Clinton rocks, round them more or less, according to their constitution, size, and length of time of exposure, and redeposit them as pebbles over some other area not far distant, where the same layer might have been less exposed or but little affected—in other words, a little farther seaward.

While, therefore, it is probable that shallow waters extended at various times over more or less of the Blue Grass region in Kentucky and Ohio, it is at no time probable that land of any great elevation was to be found here in Lower and Middle Silurian times. The land areas which did exist over these regions were always soon covered again by the sea, as far as we can judge from available information.

That land areas may have existed immediately east and south of the Blue Grass counties seems not improbable, but is not certain. The few facts known are not averse to an east and west axis of elevation south of these counties, and another one, running north and south, along the eastern border of the same. The latter axis seems to have been in process of elevation towards the close of the Lower Silurian and again during Clinton times. That this elevation was more marked on both sides of the Ohio river during Clinton times seems to be indicated by the pebbles found in Adams county, and that it increased here in importance by the fact that later the Corniferous rocks failed to appear here; and that still later the Oriskany thinned out on approaching this area.

The failure so far to discover pebbles derived from horizons decidedly below those in which they now occur imbedded, indicates that either the elevation of the land area above sea level was slight, or that it was of such short duration that erosion did not find sufficient time to produce deep river valleys or marked shore escarpments. In the case of a low dome-like elevation, the raised parts exposed to erosion would furnish the pebbles,

and these would be carried by streams or waves to less elevated regions, where they would be deposited over beds which either had not experienced erosion at all or had suffered but slightly. The pebbles would therefore be found overlying the lateral extension of the beds from which they had been derived.

It is still too early to say that marked shore escarpments did not exist. It is sufficient for the present to state that they have so far not been discovered, and that the failure of pebbles from decidedly lower horizons to appear, is decidedly against their former existence. It might be worth while to consider under what conditions such escarpments would be formed, and when they would be preserved. It is evident that during the gradual emergence of land above sea level any small escarpment formed by the sea would, on continued elevation, be exposed to aerial denudation which might accentuate it, but would be more likely to do the opposite. On the depression of the land area below the sea level, the same land surfaces would once more become a prey to the action of the waves. In either case, whether of emergence or depression, escarpments of any size would be formed only during periods when elevation or depression were at a standstill. The height of these escarpments would be determined by the slope of the land surface and the sea bottom leading up to the same, and by the length of time during which the land would admit of attack at practically the same levels. The best escarpments would not be formed during the rise of a land area, when the waters nearer the line of attack upon any shore would gradually grow shallower, but during the depression of the same, when any advantage gained by cutting through several layers of some bedded series of rocks was hardly likely to be lost, as the gradual increase in depth at this point permitted the more violent impact of the waves. Any fairly rapid period of depression would then preserve such an escarpment in good form for the future geologist.

The failure to find evidence of an escarpment may be proof merely that there were no long periods of rest either during the elevation or depression of the land area.

If the elevation of land had been at all considerable, river valleys should sooner or later have been formed of sufficient depth to insure their preservation under the accumulating débris as the land gradually sank under the sea. The upper banks of these rivers would in this process form shores of the sea or inlets, with however a possibility of being less subjected to the brunt of the waves, and hence a better chance for preservation than more exposed shores.

Nothing of the kind has so far been found in the area here studied. Conglomerates have been found, but the age of the pebbles forming the same is rather in favor of but low elevation, so low that even in the Clinton, with its small thickness of thirty-five feet, and its pebbles at times only fifteen to twenty feet above the bottom, no pebbles of Lower Silurian origin have been found. The pebbles, on the contrary, are now found only a very short distance above the horizons to which they originally belonged. This certainly suggests but a low elevation of these Silurian land areas, at least where so far examined.

The point of greatest interest in all these facts lies, therefore, in the evidence of conglomerates over a considerable area, in conjunction with equally clear evidence of their production without the assistance of any marked elevation.

AUG. F. FOERSTE.